From: Rochlin, Kevin
Sent: Thursday, May 22, 2014 11:04 AM
To: Barbara Ritchie
Subject: Standard Error vs Standard Deviation for the gamma cap

Barbara,

Per EPA direction in our conference call last Friday, FMC will proceed with preparing a Work Plan for the revised gamma study. The plan will provide an explanation and demonstrate of the statistics which FMC plans to use for the study.

Based on the discussion, FMC currently plans on using Standard Error rather than Standard Deviation as the defining statistic. As we expressed during the call, EPA still does not believe that this is the correct statistic to use, but we are willing to see what FMC proposes.

I have included a lengthy discussion below. But a description below for why in practice this statistic does not work:

Assume that we have a well characterized background (from an extremely large sample size), but that there is a large variance in background. In that case, the standard deviation about the mean will be large, but the standard error is small as the measure divides standard deviation by the square of the sample number.

Using a standard error confidence interval, if you take a measurement at a point where background is substantially higher than the mean, the result would be a cap failure. Examples are given below.

We can either discuss this in advance or wait for your work plan.

Kevin Rochlin

Strictly speaking, MARSSIM compares the site mean to the background mean. The MARSSIM decision rule is "If the difference between the mean concentration in the survey unit and the mean concentration in the reference area is less than the investigation level, then the survey unit is in compliance with the release criterion." (MARSSIM, App D, p D-10.)

Yes, we are trying to find the mean of this site, but then we are trying to compare it to the background mean to see if the difference is within 2.8 uR/hr at a 95% confidence level. To do so, we use the **standard deviation** of the background distribution because that is how we know if the site is "different than background". it represents the variability of background. <u>I find no reference in MARSSIM to the use of "standard error", which is a measure of the precision of the background mean estimate.</u>

Counter-example:
To figure out what your instrument could be able to measure "above background", you have to look at the range of background, not the range of your estimate of the background mean. You could have a wide distribution of background and a very narrow range of the estimate of the mean. Say your background standard deviation was 10 around a mean of 100. Say also that your mean is well-known and the standard error of the mean was 0.1. Would that mean that your MDC was 4.65 x 0.1 = 0.465??? That would say that you claim to detect a level of 100.465 as being "above background" when the (1 sigma) range of background is 90-110!!!! This makes no sense.

From MARSSIM p. 5-26:
The absolute size of the shift is actually of less importance than the relative shift,(delta/sigma), where sigma is an estimate of the standard deviation of the measured values in the survey unit. <u>This estimate of sigma includes both the real spatial variability in the quantity being measured and the precision of the chosen measurement system.</u>

And from MARSSIM p. 6-35:
"From a conservative point of view, it is better to overestimate the MDC for a measurement method. Therefore, when

calculating MDC and L_c values, a measurement system background value should be selected that represents the high end of what is expected for a particular measurement method. For direct measurements, probes will be moved from point to point and, as a result, it is expected that the background will most likely vary significantly due to variations in background, source materials, and changes in geometry and shielding."

So I think FMC is just wrong in thinking that MDC can be calculated based on "standard error or the mean" . I guess it remains to be seen what results they get from background studies with sodium iodide.

MARSSIM App D, p D-14 addresses this situation:

"The estimate of the standard deviation for the measurements performed in a survey unit ($sigma_s$) includes the individual measurement uncertainty as well as the spatial and temporal variations captured by the survey design. For this reason, individual measurement uncertainties are not used during the final status survey data assessment. However, individual measurement uncertainties may be useful for determining an *a priori* estimate of sigma during survey planning. Since a larger value of sigma results in an increased number of measurements needed to demonstrate compliance during the final status survey, the decision maker may seek to reduce measurement uncertainty through various methods (*e.g.*, different instrumentation). There are trade-offs that should be considered during survey planning. For example, the costs associated with performing additional measurements with an inexpensive measurement system may be less than the costs associated with a measurement system with better sensitivity (*i.e.*, lower measurement uncertainty, lower minimum detectable concentration). However, the more expensive measurement system with better sensitivity may reduce $sigma_s$ and the number of measurements used to demonstrate compliance to the point where it is more cost effective to use the more expensive measurement system. For surveys in the early stages of the Radiation Survey and Site Investigation Process, the measurement uncertainty and instrument sensitivity become even more important. During scoping, characterization, and remedial action support surveys, decisions about classification and remediation are made based on a limited number of measurements. When the measurement uncertainty or the instrument sensitivity values approach the value of the DCGL, it becomes more difficult to make these decisions. From an operational standpoint, when operators of a measurement system have an *a priori* understanding of the sensitivity and potential measurement uncertainties, they are able to recognize and respond to conditions that may warrant further investigation—*e.g.*, changes in background radiation levels, the presence of areas of elevated activity, measurement system failure or degradation, *etc."*

And MARSSIM App D, p D-20 makes the case for better instrumentation (e.g. In-Situ Gamma Spec):

"Another way to make sigma small is by using more precise measurement methods. The more precise methods might be more expensive, but this may be compensated for by the decrease in the number of required measurements. One example would be in using a radionuclide specific method rather than gross radioactivity measurements for residual radioactivity that does not appear in background. This would eliminate the variability in background from sigma, and would also eliminate the need for reference area measurements."

Finally, MARSSIM p. 6-44 addresses the use of analytically-determined sodium iodide response in NUREG 1507 (the idea I offered to start the last call):

"For a particular gamma energy, the relationship of NaI(Tl) scintillation detector count rate and exposure rate may be determined analytically (in cpm per μR/h). The approach used to determine the gamma fluence rate necessary to yield a fixed exposure rate (1 μR/h)—as a function of gamma energy—is provided in NUREG-1507 (NRC 1997b). The NaI(Tl)scintillation detector response (cpm) is related to the fluence rate at specific energies, considering the detector's efficiency (probability of interaction) at each energy. From this, the NaI(Tl)scintillation detector versus exposure rates for varying gamma energies are determined. Once the relationship between the NaI(Tl) scintillation detector response (cpm) and the exposure rate is established, the $MDCR_{surveyor}$ (in cpm) of the NaI(Tl) scintillation detector can be related to the minimum detectable net exposure rate."

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